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REPRODUCIBILITY OF REFLECTIONS FROM THE BOTTOM OF THE OCEAN,(U)

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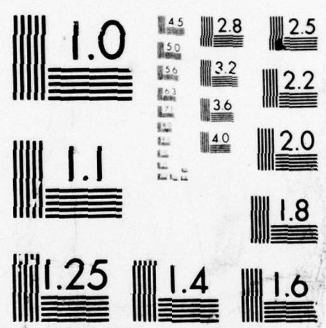

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REPRODUCIBILITY OF REFLECTIONS FROM THE BOTTOM OF THE OCEAN *†‡

by

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C. S. Clay and W. L. Liang

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ABSTRACT

The signals reflected by the bottom of the ocean are complex and dependent upon the location. Seismic profiling data were taken in typically smooth and rough areas. The similarity of reflection signals as a function of the ship's position was studied for the areas. A portion of the reflection signal for a transmission was stored in a Deltic memory. The cross correlation of reflection signals from subsequent transmissions and the stored signal was measured. In smooth areas the correlation of subsequent transmissions with the reference was about the same as the autocorrelation for over 0.5 nm translations. In rough areas, the correlations of the reference and subsequent transmissions were very small.

INTRODUCTION

Frequently in acoustical experiments one needs to know the bottom reflectivity. We should be careful to describe what we mean by the reflectivity of the ocean bottom because the reflectivity is dependent upon the roughness of the bottom, density and velocity, and subbottom layers. The roughness of the bottom is dependent upon the location, and parenthetically we remark that the bottom is rough when the mean square height of the irregularities are of the order of the acoustical wavelength. The acoustical velocity and density of the bottom depend upon the deposition of sediments in the area. All of the properties are very much a function of the location.

So let us go out on the ocean to measure the reflectivity of the ocean bottom. At a very precise location (a statistical sample chosen with a dart), the Captain calls the Laboratory and informs the Chief Scientist, "We are here." The drama commences. The Scientists look over the rail of the ship at the water, and it looks much the same as the water observed an hour earlier and probably as it will look for the duration of the experiment. The source is placed in the water, the hydrophone is placed in the water, and the equipment is turned on. What follows is well known to those who have done it, and others wouldn't understand, so we simply refer to Fig. 1 and show the basic equipment used to measure bottom reflectivity.[1,2] The

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[1] C. S. Clay and W. L. Liang, "Continuous seismic profiling with matched filter detector," Geophysics <u>27</u>, 786-795 (1962).

[2] C. S. Clay, W. L. Liang, and Serge Wisotsky, "Seismic profiling with a hydroacoustic transducer and correlation receiver," J. Geophys. Res. <u>69</u>, 3419-3428 (1964).

source transmits a signal that reflects off the bottom and is received by the hydrophone. The signal is amplified, filtered, and recorded.

Let us assume the equipment works and we have the measurement – what does it mean? Second question, does it make much difference where we made it? To gain a little insight into these questions, we compare two seismic profiles and their locations as shown in Fig. 2.[3] The lower profile was taken in a smooth area of the Hatteras Abyssal Plain; the upper profile was taken on the continental rise. The lower profile shows continuous reflections and subbottom reflections of several miles' distance, whereas the upper profile shows reflections that are discontinuous and rather chaotic. These data indicate that there are substantial differences in the reflection of signals in deep water and that the same experiment repeated in different areas can give quite different results.

SEISMIC REFLECTION EXPERIMENTS

A qualitative observation that the reflections in one area appear to be alike from one measurement to the next (each signal transmission and reflection is a measurement) and dissimilar in others can be examined quantitatively. The usual technique is to calculate the cross correlation of the signal observed at one location with a signal observed at another. The technique we used is shown in Fig. 3. One second of the reflected signal is stored in the reference channel, and the cross correlation between

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[3] P. A. Rona and C. S. Clay, (A) "Continuous seismic profiles from the continental terrace, deep-sea fan and abyssal plain off Cape Hatteras," Trans. Am. Geophys. Union 46, 103 (1965).

the stored signal and subsequent signals is computed for each signal. The particular correlator used in this study carried the sign and three bits of amplitude data.

A sequence of the oscillograph recordings is shown in Fig. 4. The data used for this figure were taken in the smooth area (the lower profile in Fig. 2), and the correlator output has the same power spectrum as the signal. The signal is peaked at about 115 cps. The autocorrelation function is the top trace, and the correlation of successive signals with the reference is the sequence of traces in the figure. Each signal transmission was repeated after about 60 to 70 meters of translation of source and receiver. From this figure it is evident that the correlation of the bottom reflection is roughly one for as much as 1.2 kilometer translation. Since measurements were made of the reflected signals, and not the envelopes of the signals, this means the reflections are alike to the highest signal frequency, 130 cps.

Beckmann and Spizzichino[4] show that the coherent reflection coefficient $\langle \mathcal{R} \rangle$ at an irregular interface is approximately the following:

$$\langle \mathcal{R}_{12} \rangle \doteq R_{12}\, e^{-2k_z^2 \sigma^2} \qquad (1)$$

where R_{12} is the reflection coefficient for a smooth interface, k_z is the vertical component of the incident wave number, and σ is the rms roughness of the irregular interface. If we assume that the correlation of

[4] P. Beckmann and A. Spizzichino, The Scattering of Electromagnetic Waves from Rough Surfaces (The Macmillan Company, New York, 1963).

subsequent reflections means that $2k_z^2\sigma^2$ is less than one, then σ is less than 2 meters. The 400-cps reflection studies of Clay and Rona[5] indicate with the same criterion that σ is less than 0.4 meters in the Hatteras Abyssal Plain. A section of seismic profile taken in this area is shown in Fig. 5. It is evident that the subbottom reflections are similar over this distance even though one cannot see the phases of the signals.

A seismic profile in the rough area is shown in Fig. 6. The correlation study in this area is shown in Fig. 7. The peak of the autocorrelation is indicated with a little dash. The reflection from the bottom cannot be identified on any of the subsequent traces.

The reflected signal is the sum of all of the signals scattered and reflected at the bottom. Since the correlation of subsequent signals with the first is small, the particular combination of reflected signals observed at one position is not like the signal observed at a nearby position. The frequency used in this study is too high to estimate the roughness; however the roughness is considerably greater than 2 meters.

CONCLUSIONS

In the middle of the smooth area, i.e., the Hatteras Abyssal Plain, the reflections from the bottom and subbottom are uniform for transmissions of the order of kilometers. In the rough area the reflections are different for transmissions as small as 60 to 70 meters and this is in 5 kilometers

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[5] C. S. Clay and P. A. Rona, "Studies of seismic reflections from thin layers on the ocean bottom in the Western North Atlantic," J. Geophys. Res. 70, 855-869 (1965).

of water depth. These experiments confirm the observation of Rona and Clay[3] that the signal reflected by the ocean bottom is very dependent upon the location of the experiment. Experiments performed in rough areas would yield different results for trivial changes of position. Experiments performed in very flat areas should be insensitive to small changes of position. Since the amplitude and coherence of the signal are very dependent upon the roughness of the ocean bottom, it would appear desirable to concentrate our initial studies of bottom-reflectivity in the smooth areas where data should be reproduceable. The results reported in this paper are related to the coherent reflection in a yes or no sense. Reflection measurements that do not determine the partition of energy between coherent and incoherent components cannot be interpreted to yield bottom parameters because the scattering and reflection formulae are very different for the two components.[4, 6]

ACKNOWLEDGMENTS

Mr. Peter Rona and Mr. John Smith obtained the seismic profiles in the Hatteras Abyssal Plain and on the continental rise.

[6] C. S. Clay and H. Medwin, "High-frequency acoustical reverberation from a rough-sea surface," J. Acoust Soc. Am. 36, 2131-2134 (1964).

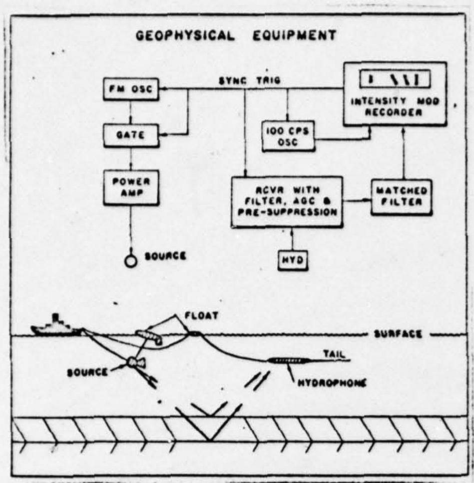

Fig. 1. Continuous seismic profiling system. A 4-sec coded signal in which the source frequency varied between about 100 and 130 cps was used in the profiling experiments. The energy radiated in each chirp was about 120 joules. A Deltic correlator was used for the matched filter.

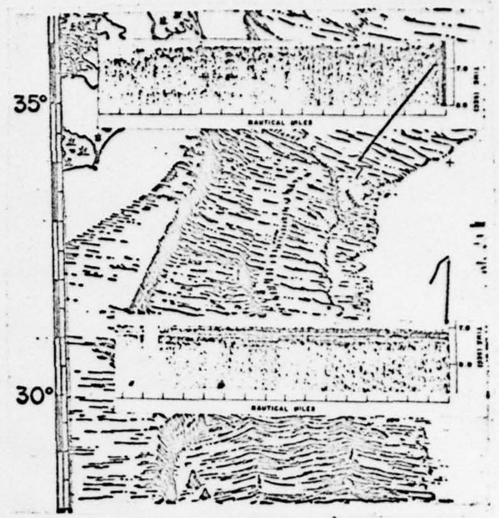

Fig. 2. Location of the profiles are shown on the chart of Heezen and Thorp. The reflection times are two-way travel times.

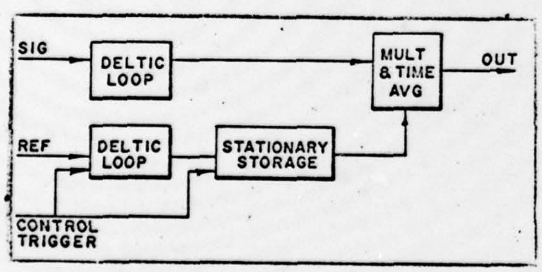

Fig. 3. Deltic correlator. The cross correlation of the signal with the stored reference is calculated in real time.

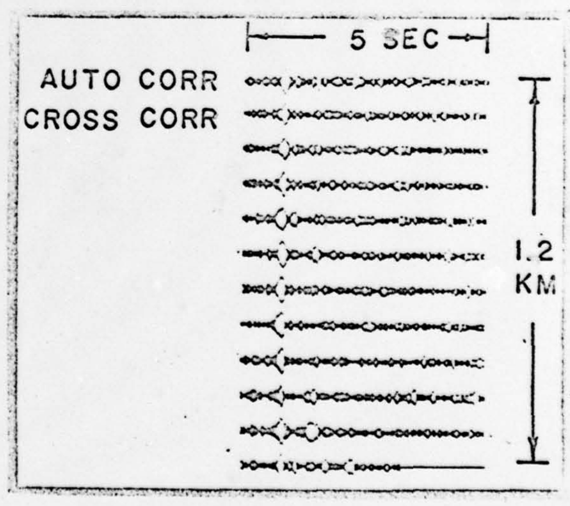

Fig. 4. The cross-correlation smooth area. The first second of signal reflected by the bottom and subbottom was stored as the reference. Subsequent reflected signals are correlated against the stored reference. The data were taken in the smooth area - the lower profile in Fig. 2.

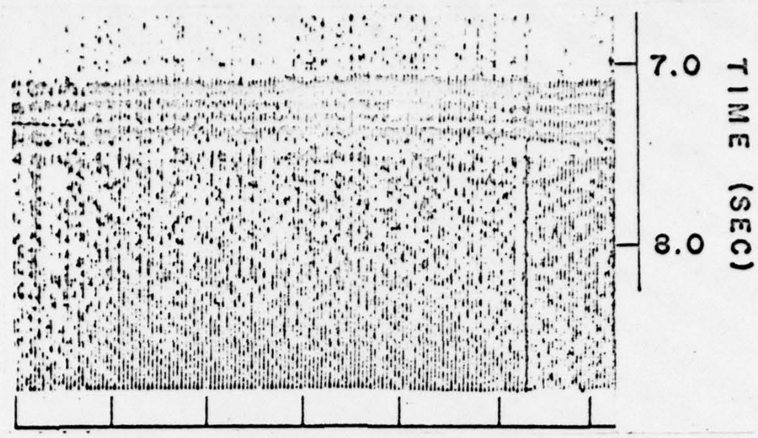

Fig. 5. Enlarged display of profile in the smooth area - Hatteras Abyssal Plain. The horizontal scale is in nautical miles.

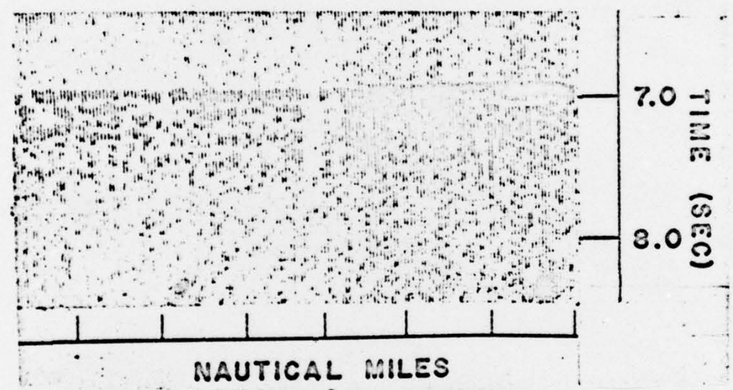

Fig. 6. Enlarged display of the profile from the rough area - continental rise.

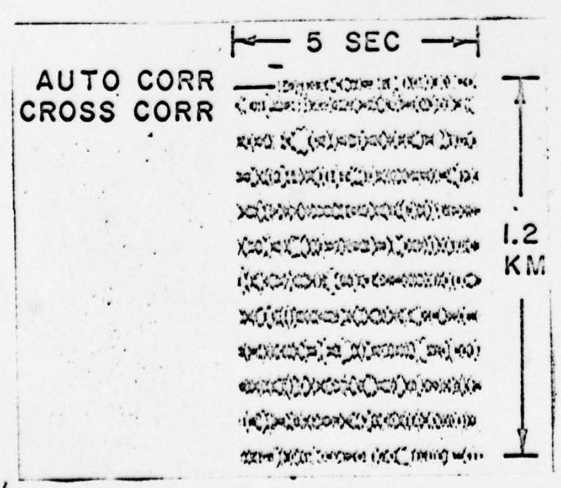

Fig. 7. Correlation of subsequent bottom reflections in the rough area. The first trace is the autocorrelation, where the peak is indicated by the horizontal dash.